

Hourly SCOPF Simulations

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Overview

- Over the last several years we've been developing capability to do time-domain (hourly) OPF or SCOPF studies
 - it does “hourly snapshots” without unit commitment
- This tool has been used for studies for TVA and the Illinois Commerce Commission
- Tool can use either the ac or the dc power flow models
- It is not yet a “released” product

Hourly OPF/SCOPF Simulation Form

Hourly LMP Simulation Form

Starting Time: 7/1/2007 1:00 AM Do Run Read Data Binary Clear Results Last Result:

Ending Time: 8/1/2007 12:00 AM Do Single Point Read Load Format Delete All Read Data From Excel Open Data File

Refresh All Displays Each Time Step Reset Run Save Data Binary

Hourly Summary | Input | Tieline Matching | Results: Constraints | Results: Bus/Gen Values | Results: Custom | Options | TSB Case Description

	Date	Hour	Skip	Tieline Flows	Processed	Solution Type	Solved	Num Loads	Total MW Load	Total Mvar Load	Num Gens	Total MW Gen	Num
1	7/1/2007	1:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
2	7/1/2007	2:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
3	7/1/2007	3:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
4	7/1/2007	4:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
5	7/1/2007	5:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
6	7/1/2007	6:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
7	7/1/2007	7:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
8	7/1/2007	8:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
9	7/1/2007	9:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
10	7/1/2007	10:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
11	7/1/2007	11:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
12	7/1/2007	12:00 PM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
13	7/1/2007	1:00 PM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
14	7/1/2007	2:00 PM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
15	7/1/2007	3:00 PM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
16	7/1/2007	4:00 PM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
17	7/1/2007	5:00 PM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
18	7/1/2007	6:00 PM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
19	7/1/2007	7:00 PM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
20	7/1/2007	8:00 PM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
21	7/1/2007	9:00 PM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
22	7/1/2007	10:00 PM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
23	7/1/2007	11:00 PM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
24	7/2/2007	12:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	

Close Cancel

TVA Project Hourly Simulation

- For the TVA project the following was done each hour:
 - set power flow to contain the hour's load and generation (and possibly maximum gen limits)
 - adjust external generation to match tie flows
 - perform an unconstrained OPF solution to determine hourly cost with no constraints
 - perform an SCOPF solution to determine constrained dispatch
 - store and display results

ICC Project Hourly Simulation

- The ICC project was simpler, but used a larger model (about 13,000 buses and 1300 contingencies using a dc SCOPF)
 - set the model to match the hourly values
 - perform an SCOPF
 - store and display results
- Project did hourly SCOPF for anticipated 2007 loads (8760 hours)

Hourly Inputs

- The following values are inputs
 - bus MW/Mvar load
 - actual generator MW
 - Maximum generator MW
 - Line status
 - Area loads (e.g., FERC 714 data)
- All inputs can be pasted in from Excel

Selecting Values to Save

- Running the hourly simulation can create lots of potential output. A number of options are provided to select the values to save

The screenshot shows a software interface with several panels for configuring simulation options:

- Input Options:**
 - Home Area: 147 (TVA)
 - Initially Zero All Home Area(s) Load
 - Area Load Values:**
 - Set Area Load After Scaling Individual Loads
 - Set Area Load Before Scaling Individual Loads
 - Ignore Area Load Values
- Tieline Matching Options:**
 - Store Hourly Tieline Generator MWs
 - Store Hourly Generator and Switched Shunt Mvars
 - Store Hourly Transformer LTC Taps
 - Store Hourly Phase Shifter Angles
 - Number of Penalty Function Breakpoints: 0
 - MWs per Breakpoint: 0.0
 - Maximum Number of LP Iterations: 5000
- Solution Options:**
 - Solve Unconstrained Case
 - Set Home Area Transactions to Zero ACE
 - Price Hydro Generation at Marginal Cost
 - Reset Hydro Generation Price at End of Time Period
 - Pause if Power Flow Does Not Solve
 - Use Parallel Contingency Analysis (on Dual CPU Machines)
 - Enable Power Flow Area Interchange Control
 - Number of Intermediate Points to Solve: 0
- Result Options:**
 - Save Binding Constraints
 - Save Unconstrained Generator MW Outputs
 - Save Final Generator MW Outputs
 - Save Final Bus LMPs
- Auto Contouring:**
 - Action:**
 - No Auto Contouring
 - Save in File as Bitmap
 - Contour but Do Not Save
 - Save in File as JPEG

Storing Custom Results

Custom Results Selection Dialog

Save and Close Cancel Clear All Selections

Areas Buses Generators Injection Groups Interfaces Lines **Owners** Superareas Transformers Zones

Select Owners

Owner Number	Owner Name	Time Selected
1	DefaultOwner	NO
2	80 CIN ECAR	NO
3	81 CIN EQVL	NO
4	3560 Ameren-NonIllinois	YES
5	3561 Ameren-Illinois	YES
6	3562 Ameren-CIPS	YES
7	3563 Ameren-UE	YES
8	3570 Illinois Power	YES
9	3571 Dynegy	YES
10	3572 Dynegy/NRG Energy	YES
11	3590 Ameren-CILCO	YES
12	3600 CWLP	YES
13	3610 SIPC	YES
14	3620 EEI	YES
15	3630 ComED	YES
16	3631 Exelon Generation	YES
17	3632 Exelon Nuclear/MidA	YES
18	3633 Midwest Generation I	YES
19	9900 Alleghany Power	YES
20	9905 Aquila Energy	YES
21	9910 Calpine	YES
22	9915 Calumet Energy	YES
23	9920 Constellation Power	YES
24	9925 Dominion Energy	YES
25	9930 Duke Energy	YES
26	9932 MidAmerican Energy	YES
27	9935 NRG	YES
28	9940 Power Energy Partne	YES
29	9945 PPL	YES
30	9950 Reliant Energy	YES

Available Area Fields

Hourly Costs

- Total Generator Production Cost (Unscaled)
- Total Generator Production Cost (Scaled)
- Total Generator LMP Profit

LMPs

- Weighted Average LMP
- Unweighted Average LMP
- LMP Standard Deviation (Unweighted)
- Minimum LMP
- Maximum LMP

Load/Gen Summary

- Total MW Load
- Total Mvar Load
- Total MW Generation
- Total Mvar Generation

Many different fields can be saved for the different object types shown on this dialog. Results can be stored for any of the individual objects

Running an Hourly Simulation

Start and End times

Select to start a run

Individual hours can also be run

	Date	Hour	Skip	Tieline Flows	Processed	Solution Type	Solved	Num Loads	Total MW Load	Total Mvar Load	Num Gens	Total MW Generation	Num
1	7/1/2007	1:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
2	7/1/2007	2:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
3	7/1/2007	3:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
4	7/1/2007	4:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
5	7/1/2007	5:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
6	7/1/2007	6:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
7	7/1/2007	7:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
8	7/1/2007	8:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
9	7/1/2007	9:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
10	7/1/2007	10:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	
11	7/1/2007	11:00 AM	NO	Ignore Tieline Flows	YES	SCOPF	2	0	0.0	0.0	0	0.00	

Viewing the Results

- A number of different options are provided for summarizing and viewing the results

Hourly LMP Simulation Form

Starting Time: 7/1/2007 1:00 AM Do Run Read Data Binary Clear Results Last Result:

Ending Time: 8/1/2007 12:00 AM Do Single Point Read Load Format Delete All Read Data From Excel Open Data File

Refresh All Displays Each Time Step Reset Run Save Data Binary

Hourly Summary | Input | Tieline Matching | Results: Constraints | Results: Bus/Gen Values | Results: Custom | Options | TSB Case Description

	Date	Hour	Skip	Processed	Solution Type	Solved	Initial Cost \$	Unconstrained	Unconstrained	Final Cost \$/MWh	Congestion \$	LMP Avg
1	7/1/2007	1:00 AM	NO	YES	SCOPF	2	284313.75	0.00	0.00	192588.47	192588.47	16.49
2	7/1/2007	2:00 AM	NO	YES	SCOPF	2	182173.14	0.00	0.00	185991.89	185991.89	16.23
3	7/1/2007	3:00 AM	NO	YES	SCOPF	2	177765.61	0.00	0.00	179688.44	179688.44	16.03
4	7/1/2007	4:00 AM	NO	YES	SCOPF	2	174354.83	0.00	0.00	170339.13	170339.13	15.99
5	7/1/2007	5:00 AM	NO	YES	SCOPF	2	167064.63	0.00	0.00	167699.30	167699.30	15.98
6	7/1/2007	6:00 AM	NO	YES	SCOPF	2	165483.73	0.00	0.00	166723.66	166723.66	15.98
7	7/1/2007	7:00 AM	NO	YES	SCOPF	2	165470.63	0.00	0.00	164652.02	164652.02	15.97
8	7/1/2007	8:00 AM	NO	YES	SCOPF	2	176545.73	0.00	0.00	171513.17	171513.17	15.99
9	7/1/2007	9:00 AM	NO	YES	SCOPF	2	201705.00	0.00	0.00	185982.78	185982.78	16.30
10	7/1/2007	10:00 AM	NO	YES	SCOPF	2	220216.05	0.00	0.00	205571.28	205571.28	16.73
11	7/1/2007	11:00 AM	NO	YES	SCOPF	2	234626.36	0.00	0.00	221389.84	221389.84	16.84
12	7/1/2007	12:00 PM	NO	YES	SCOPF	2	248008.72	0.00	0.00	249102.09	249102.09	16.95
13	7/1/2007	1:00 PM	NO	YES	SCOPF	2	272636.16	0.00	0.00	272617.16	272617.16	17.11
14	7/1/2007	2:00 PM	NO	YES	SCOPF	2	285154.06	0.00	0.00	275579.53	275579.53	17.66
15	7/1/2007	3:00 PM	NO	YES	SCOPF	2	280292.81	0.00	0.00	287732.22	287732.22	17.68
16	7/1/2007	4:00 PM	NO	YES	SCOPF	2	287701.41	0.00	0.00	292148.72	292148.72	18.18
17	7/1/2007	5:00 PM	NO	YES	SCOPF	2	291585.06	0.00	0.00	310019.81	310019.81	18.63
18	7/1/2007	6:00 PM	NO	YES	SCOPF	2	311975.19	0.00	0.00	328365.81	328365.81	18.87
19	7/1/2007	7:00 PM	NO	YES	SCOPF	2	325464.63	0.00	0.00	326911.97	326911.97	18.89
20	7/1/2007	8:00 PM	NO	YES	SCOPF	2	318852.38	0.00	0.00	315577.97	315577.97	18.69
21	7/1/2007	9:00 PM	NO	YES	SCOPF	2	308467.81	0.00	0.00	294273.03	294273.03	18.16
22	7/1/2007	10:00 PM	NO	YES	SCOPF	2	293778.19	0.00	0.00	291934.19	291934.19	18.16
23	7/1/2007	11:00 PM	NO	YES	SCOPF	2	281000.38	0.00	0.00	287387.63	287387.63	17.82

Results Summary | Hourly Binding Lines | Hourly Binding Interfaces | Hourly Binding Contingencies | Binding Line Summary Matrix | Binding Line Summary List

Close Cancel

Custom Results

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View/Modify Custom Result Definitions Load Custom Result Definitions Save Custom Result Definitions

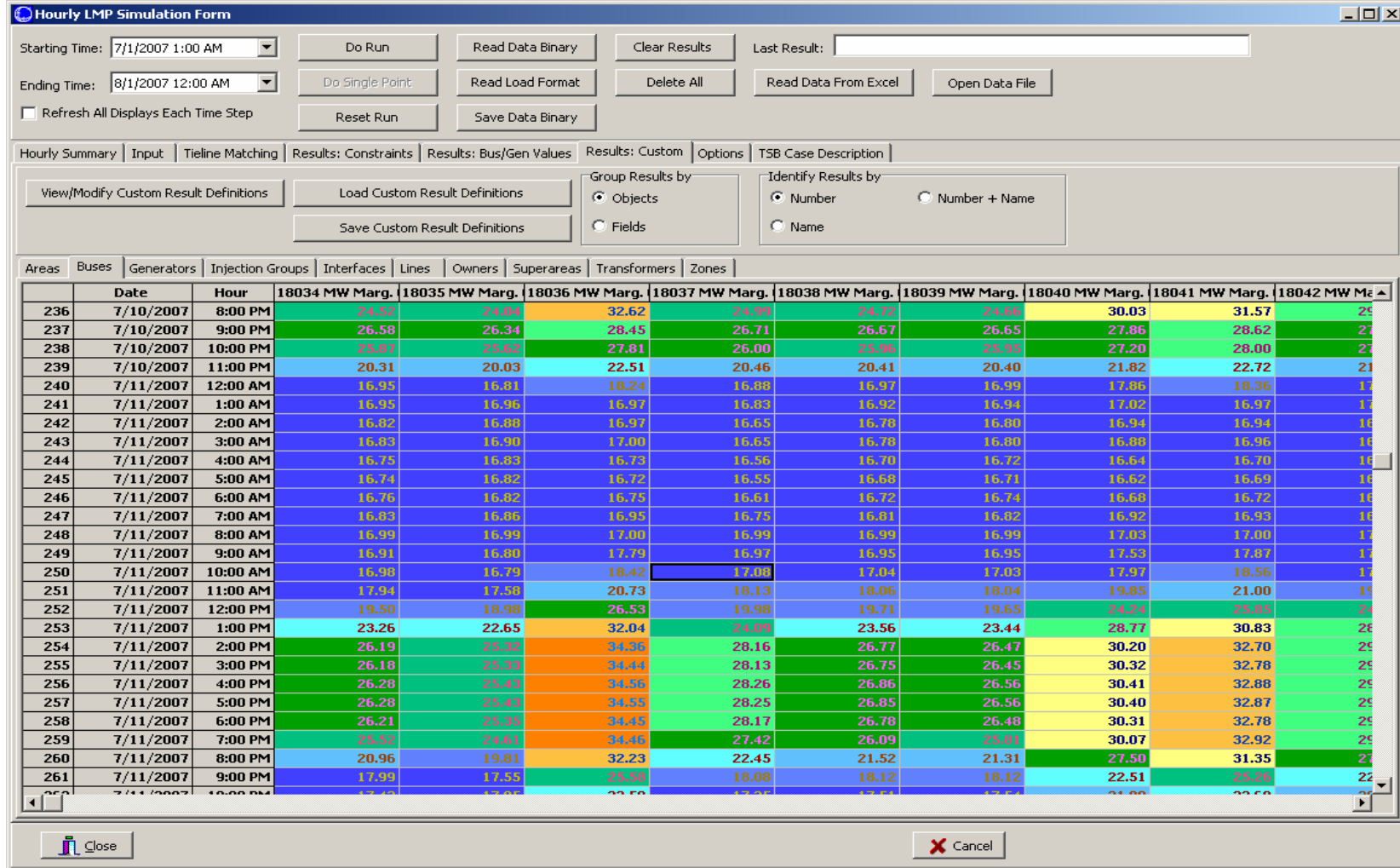
Group Results by: Objects Fields Identify Results by: Number Number + Name Name

Areas | Buses | Generators | Injection Groups | Interfaces | Lines | Owners | Superareas | Transformers | Zones

	Date	Hour	Skip	130 MW Marg. Co.	130 MW Marg. Co.	130 MW Marg. Co.	130 MW Marg. Co.	130 Int MW	147 MW Marg. Co.	147 MW Marg. Co.	147 MW Marg. Co.
1	7/1/2007	1:00 AM	NO	15.91	15.80	14.96	16.99	936.53	16.49	16.49	16.49
2	7/1/2007	2:00 AM	NO	15.65	15.56	14.78	16.04	1091.27	16.23	16.23	16.23
3	7/1/2007	3:00 AM	NO	15.25	15.15	14.47	16.13	1225.16	16.03	16.03	16.03
4	7/1/2007	4:00 AM	NO	15.19	15.10	14.48	16.23	1273.90	15.99	15.99	15.99
5	7/1/2007	5:00 AM	NO	15.13	15.04	14.47	16.71	1296.82	15.98	15.98	15.98
6	7/1/2007	6:00 AM	NO	15.12	15.03	14.48	16.88	1325.06	15.98	15.98	15.98
7	7/1/2007	7:00 AM	NO	15.13	15.05	14.51	17.04	1290.09	15.97	15.97	15.97
8	7/1/2007	8:00 AM	NO	15.22	15.13	14.54	16.39	1077.52	15.99	15.99	15.99
9	7/1/2007	9:00 AM	NO	15.96	15.90	15.28	16.20	714.39	16.30	16.30	16.30
10	7/1/2007	10:00 AM	NO	16.28	16.18	15.58	19.90	461.50	16.72	16.73	16.73
11	7/1/2007	11:00 AM	NO	16.45	16.38	15.83	17.87	260.59	16.84	16.84	16.84
12	7/1/2007	12:00 PM	NO	16.73	16.69	16.31	16.88	78.53	16.95	16.95	16.95
13	7/1/2007	1:00 PM	NO	17.05	16.97	16.38	19.65	-78.46	17.11	17.11	17.11
14	7/1/2007	2:00 PM	NO	17.92	17.72	16.72	26.92	-196.99	17.68	17.66	17.66
15	7/1/2007	3:00 PM	NO	17.94	17.74	16.71	27.20	-267.98	17.70	17.68	17.68
16	7/1/2007	4:00 PM	NO	18.51	18.14	16.14	34.70	-231.74	18.21	18.18	18.18
17	7/1/2007	5:00 PM	NO	21.75	20.96	3.74	43.07	-343.44	18.67	18.63	18.63
18	7/1/2007	6:00 PM	NO	22.54	21.62	1.40	47.67	-346.35	18.92	18.87	18.87

Close Cancel

Contouring Column Results



Binding Constraints

- Information on the SCOPF binding constraints can be shown in a number of ways
 - hourly by line/interface
 - hourly by contingency
 - line/interface by contingency matrix
 - summary list by line/interface

Binding Line Summary

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	Number	Name	Number	Name	Circuit	Lim MYA	Total Hrs	Total Hrs Uneq	Contingency Name	Hours Bindin	Avg MC	Max MC	Min f
1	39245	ARP 138	39244	ARP 345	1	336	1726	0	WIS39244ARP345-39785R	1726	22.92	129.52	
2	31375	ORAN	31790	STODDARD	1	132	974	0	AMRNMTL51	974	44.53	179.41	
3	30583	FRED TAP	30586	FREDTOWN	1	191	940	0	AMRNMTL73	940	16.91	150.72	
4	38852	BAIN 5	38851	PLS PR4	2	336	584	0	WIS38850PLSPR3-38851P	584	9.08	49.53	
5	39058	PAD 345	39059	PAD 138	1	560	547	0	WIS39058PAD345-39119R	547	19.33	70.12	
6	18422	8JVILLE	18425	8CUMBERL	1	2597	438	0	TVA184258CUMBERL-1843	438	14.37	37.76	
7	27567	14MORGAN	33356	2GALTN_5	1	36	530	0	SIPC2761814LIVIN5-3335	413	6.72	20.80	
8	36969	MAZON; R	37085	OGLES; T	1	86	754	0	345-L15502_B-R	365	13.29	60.49	
9	32291	LAC N TP	32298	GILSP TP	1	164	416	0	AMRNMTL71A	358	7.84	12.30	
10	18425	8CUMBERL	18430	8DAVIDSO	1	2597	250	0	TVA184228JVILLE-184258	250	0.85	13.47	
11	36737	FISK ; R	37546	FISK STR	19	190	222	0	TR81_TAYLR_R-C	222	20.72	155.70	
12	31024	MARIES	96096	5MARIES	1	100	220	0	AMRNV5517	220	71.23	198.26	
13	25408	08WEBSTE	25411	08NEWLON	1	478	213	0	AEP2266505GRNTWN-2266	211	4.06	44.02	
14	36969	MAZON; R	37085	OGLES; T	1	86	754	0	345-L2101-5	169	6.71	61.86	
15	36736	FISK ; B	37546	FISK STR	19	190	159	0	TR82_TAYLR_B-C	159	9.90	28.46	
16	37261	SLINE;55	37317	WASHI; R	1	205	159	0	345-L17723_B-C	159	12.11	141.11	
17	64404	DAVNPRT3	64409	WALCOTT3	1	956	154	0	MEC64402LOUISA3-64403	154	1.94	5.60	
18	39214	EDG 345	39396	CEDRSAUK	1	590	161	0	WIS38870GRANVL2-39433	153	0.67	2.77	
19	31054	MASON CY	32410	1346A TP	1	137	137	0	CIL-6	136	2.20	8.03	
20	36624	CLYBD; B	36648	CROSB; B	1	220	227	0	345-L4621_B-N	133	1.93	31.42	
21	36421	ZION; R	38849	PLS PR2	1	1195	146	0	345-L17101-R	125	0.16	0.76	
22	36969	MAZON; R	37085	OGLES; T	1	86	754	0	IP108	123	6.31	62.76	
23	36298	DAVIS; B	36027	DAVIS;3M	1	398	120	0	345-L17704_R-5	120	82.60	546.83	
24	36718	ELMHU;3I	36758	F PAR; B	1	250	115	0	TR81_ELMHU_R-N	115	8.83	140.69	

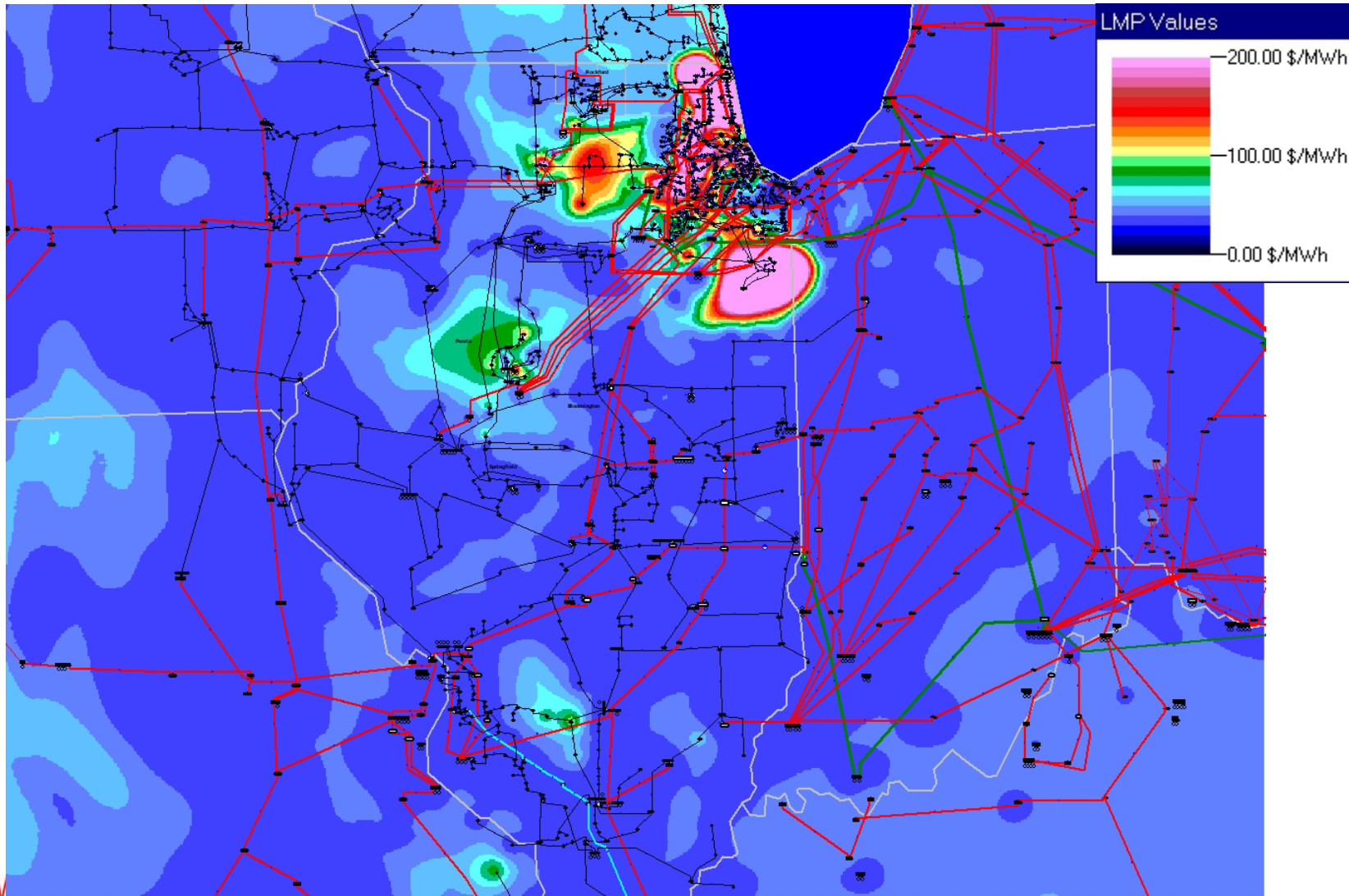
Results Summary | Hourly Binding Lines | Hourly Binding Interfaces | Hourly Binding Contingencies | Binding Line Summary Matrix | Binding Line Summary List

Close Cancel

Contouring Results

- Results can be contoured either for individual hours, or for a number of hours
 - individual hourly contours can be created and saved automatically, allowing the creation of movies
 - summary contours are made using the “Transfer Results Back to Power System” on Buses Custom Results form
 - this allows contouring averages, min/max, and number of times above/below a threshold value

Example Illinois Results: Highest LMPs in 2007 Qtr 3



Storage of Inputs/Results

- Inputs and results are stored in *.tsb files (time series binary)
 - these files can get quite big, particularly when storing lots of results
 - For example, ICC results are stored by month, with each monthly tsb being > 50 MB.

Where Do We Go From Here?

- The hourly SCOPF simulation tool has been quite useful for the TVA and ComED projects
- Over the last year or so it has gotten much more general, able to save many different values
- The hourly input is still somewhat limited
- Should this be a released product?